Political Geography 69 (2019) 162–172

Contents lists available at ScienceDirect

Political Geography

journal homepage: www.elsevier.com/locate/polgeo

Do treaties matter? Climate change, water variability, and cooperation along transboundary river basins

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ARTICLE INFO

Keywords:
Water variability
Climate change
International water treaties
Conflict
Cooperation

ABSTRACT

Annual and seasonal water variability is predicted to intensify due to climate change. River basins lacking institutional capacity, such as treaties, to deal with environmental change may experience political tensions. Using the 1948–2008 country dyads event data from the Basins at Risk project, this paper investigates whether basins governed by treaties witness less tensions and/or more cooperation over shared water relative to those basins not governed by treaties. It also evaluates basins pre- and post-treaty enactment. The results provide only limited support for the claim that the presence of a treaty does in fact promote cooperation, but provide stronger support for the claim that the number of agreements between riparians enhances cooperation particularly when taking into consideration water variability. This variable is significantly and positively correlated with increased cooperation – a finding that is robust across different specifications controlling for a broad set of climatic, geographic, political, and economic variables. This may indicate that successive treaties successfully address some of the shortcomings of their predecessors. Importantly, when disaggregating conflictive and cooperative events, the research does not find support for the claim that treaties or number of treaties reduce conflict. This may highlight the importance of the need to treat conflict and cooperation individually and not simply as opposite poles of a single spectrum.

Introduction

Climate change is predicted to affect the variability of river flows and have a variety of additional impacts on the hydrologic cycle (Jury & Vaux, 2005; Miller & Yates, 2006). The change in flow variability will affect populations that will be less able to rely on current water availability and supply trends (Milly et al., 2008).

Increased hydrologic variability may create a significant challenge especially for countries sharing international river basins. Unanticipated high or low flow events may lead to flooding, severe drought, damages to infrastructure, loss of human life, and water resource disputes. Some observers have stressed that, be it in the form of heightened political tensions or more extreme violent exchanges, climate change and the projected increase in water variability may further complicate existing shared water management strategies and may have significant economic, social, environmental, and political consequences (Adger, Hughes, Folke, Carpenter, & Rockström, 2005; Walker et al., 2006).[2] This analysis is guided by the general concern that climatic change and subsequent water variability may create transboundary water governance complications (Cooley & Gleick, 2011).

Given the links among climate change, water variability, and the possibility of inter-state tensions, the role of institutions in assuaging potential conflicts and promoting cooperation between states seems paramount (Salehyan, 2008). While it is true that many forms of environmental cooperation are not codified in international agreements, and agreements may not always curtail free-riding, or cheating, treaties constitute an important governing apparatus over shared water resources. Guided by the extant literature that focuses on international

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[2] For a critical perspective of the climate change-conflict thesis see Böhmelt et al., 2014; Buhaug, 2015, Selby et al., 2018.

https://doi.org/10.1016/j.polgeo.2018.08.007
Received 24 July 2017; Received in revised form 24 July 2018; Accepted 14 August 2018
Available online 03 December 2018
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water treaties as a formal measurement of inter-state coordination, this study explores if and by how much the presence of an international water treaty (or treaties), in fact, makes a difference and reduces conflict and/or promotes increased cooperation particularly under conditions of increased variability. Below, we begin by reviewing the literature juxtaposing studies that tout the importance of treaties with those studies more critical of the value of water treaties and related measures of cooperation. We then present a description of our sample, variables and hypotheses. This is followed by a description of the methodology and a presentation of results. Finally, we conclude with policy implications and recommendations.

How important are treaties?

Scholars have long touted the importance of treaties in promoting cooperation and preventing or assuaging disputes among countries (Mitchell, 2006). Although signing a treaty does not guarantee stable cooperation, analysts have claimed that treaties may provide states with a structured means to organize their relations and manage disputes (Downs, Rocke, & Barsoom, 1996; Weiss & Jacobson, 1998). According to Chayes and Chayes (1993), treaties alter states' behavior, their respective relationships, and their expectations of one another, creating a framework for extended interaction. According to Barrett, treaties help states coordinate their actions, especially when unilateralism fails to sustain a mutually satisfying outcome and to prevent free-riding (Barrett, 2003, xiii).

Specific to water treaties, McCaffrey (2003:157) has claimed, "treaties stabilize [the relations of states sharing a river] giving them a level of certainty and predictability that is often not present otherwise." Such stability may be particularly relevant under changing conditions (hydrological or otherwise). Wolf, Stahl and Macomber (2003) and Stahl (2005), for example, hypothesized and provided evidence that the likelihood of political tensions is related to the interaction between rates of change (physical or institutional) within a basin, and the absence of institutions (such as treaties) to absorb that change. Case studies pertaining to specific transboundary basins have also considered the value of treaties for promoting cooperation. In her study of the Indus Basin and the 1960 Indus Water Treaty, Zawahri (2009) found that the treaty's Permanent Indus Commission (PIC) has played an invaluable role in the treaty's implementation since 1960. Biswas (2011) suggested that both India-Bhutan have benefitted from cooperation over hydropower development, governed by a treaty, and have leveraged the success of their first project—the Chukha Hydroelectric project—to develop new opportunities for cooperation.

Empirical studies, utilizing larger datasets and statistical methods, have also explored arguments pertaining to treaties and cooperation. Findings by Brochmann and Hensel (2011; 2009) suggest that while the existence of river treaties does not necessarily prevent disagreements (operationalized as conflicting country claims) between states over their shared water resources, the presence of at least one treaty over the specific subject of the claim reduces the likelihood that the claim becomes militarized. In addition, the authors found that the treaties are associated with substantial increases in the likelihood of negotiations over such claims. Examining post-treaty cooperation in the form of cooperative water events, Brochmann (2012) finds an increased probability that treaty signatories experience more cooperation (as measured by water-related events) than do non-signatories. This is most salient during the immediate years following the signing of the treaty.

Additional research examines the impact of treaty design. De Stefano and colleagues, for example, mapped institutional capacity and combined that information with both historic and projected water variability (De Stefano et al., 2012) as well as other factors that could exacerbate transboundary tensions (De Stefano, Petersen-Perlman, Sproles, Eynard, & Wolf, 2017). In addition to mapping whether the basin is governed by a treaty, the authors considered whether any of the treaties codify mechanisms including water allocation, water variability management, conflict resolution, and a joint commission. Tir and Stinnett (2012) considered whether treaties with such institutional mechanisms as monitoring, conflict resolution, enforcement, and joint commission help assuage conflict. Using the extent of military conflict between states as their dependent variable, the authors found that conflict is mitigated the higher the number of the above-mentioned mechanisms are codified in the treaty. Utilizing a combined measure of conflict and cooperation (derived from the Basins at Risk project) as a dependent variable, Dinar, Katz, De Stefano, and Blankespoor (2015) found similar results pertaining to institutional mechanisms, and, building on the work of Drieschova, Giordano and Fishhendler (2008), also found that water allocation mechanisms that engender both flexibility and specificity are associated with a higher BAR score, implying more cooperation and/or reduced conflict over water. Mitchell and Zawahri (2015) found that along with an enforcement mechanism, treaties with information and data exchange mechanisms seem to engender lower militarization of contentious river claims while increasing the chances that negotiations over river claims successfully resolve the issues at stake. Link et al. (2016) also suggested that robust treaties and institutions can mitigate water-related conflict and facilitate cooperation under hydrological stress.

Critical studies investigating the notion of water cooperation and formalized environmental agreements have come to different conclusions regarding international water treaties. Bernauer (1997; 2002) claimed that while some river management institutions appear to work well, "the performance of others leaves much to be desired and some arrangements have remained only 'paper tigers'." Conca (2002) surmised that governments are willing to enter into international agreements when the costs of doing so are low and that many environmental accords lack significant power to bind states. Following these arguments, Dombrowsky (2007) claimed that the mere presence of an international water treaty does not provide any guarantee that it will ultimately contribute towards sustained cooperation. For one, cooperation depends on both the intentions of the states involved and their capacity to carry out treaty provisions, which may be lacking (Karreth & Tir, 2018; Nakayama, 1997).

While much of the literature on transboundary hydropolitics has treated conflict and cooperation as opposite ends of a spectrum, several scholars have objected to this approach, noting both that conflict and cooperation can coexist, and that not all cooperation is positive and not all conflict is negative (e.g., Zeitoun and Mirumachi (2008)). In addition, Zeitoun and Warner (2006) take issue with the entire notion of 'cooperation over water'. The authors claim that in many cases, treaties only institutionalize innate power relations in a basin. Furthermore, the authors claim, a reduction in conflict or the appearance of any "cooperative" behavior observed may really be efforts of the basin hegemon to impose a particular regime. Similar arguments pertaining to the influence of hydro-hegemons have been offered in the cases of water relations between Israelis and Palestinians since the 1995 Oslo II Agreement (Selby, 2003), the Tigris-Euphrates Basin (Warner, 2008) and the Aral Sea Basin (Menga, 2016). According to Gupta (2016), even the UN Convention on the Law of Non-navigational Uses of International Watercourses is undermined by hydro-hegemonic influences. Broadly critical of international water treaties, Conca (2006) argued that agreements are neither the only nor the most effective way of addressing transboundary water issues and points at other forms of governance (e.g. expert networks) to demonstrate how environmental problems can be resolved.

Some empirical studies have also found nuance related to the efficacy of treaties. Brochmann and Gleditsch (2012) found that the presence of a treaty does not necessarily guarantee successful negotiations over claims and a subsequent end to the claims. Scholars have also questioned arguments made about the importance of treaty design suggesting that it is still unclear whether institutional features uniformly improve water relations among countries (Bernauer & Kalbhenn, 2010).

Couched in the above debate and inspired by the works of Brochmann (2012) and De Stefano et al. (2012; 2017), which constitute three major systematic works that explore whether treaties promote cooperation among basin states, our study empirically evaluates whether basins governed by treaties experience more or less cooperation and/or conflict than those not governed by treaties—particularly under conditions of climatic variability. While we acknowledge that cooperation can take on various forms and may be subject to various influences, we limit our dependent variable to the systematic data available in the Basins at Risk (BAR) database, which accounts for conflictive and cooperative water-related events. The BAR database identifies water related events that occur within an international river basin. The conflictive and cooperative events data span a variety of issues and fall under varying degrees of intensity (seven intensity levels for conflict and seven for cooperation).

This study goes beyond the existing literature in several ways. First, in contrast to De Stefano et al. (2012; 2017), we subject a number of variables to a large-n empirical investigation, examining the relationship among the presence, and number, of treaties and water variability as well as level of conflict and cooperation among riparians.[3] Second, and in comparison to Brochmann (2012), which uses a similar dependent variable based on the BAR dataset, we consider a longer period of time (1948–2008 versus Brochmann's 1948–1999) and, we consider both pre- and post-treaty periods for basins.[4] In addition, we consider the number of treaties in our analysis, and not just the mere presence/absence of a treaty. Third, we examine whether water variability impacts basin resilience given the existence (or absence) of a treaty and number of treaties. Fourth, our dependent variable is calculated over time rather than limited to a specific year. Fifth, we use as our dependent variable both a combined measure of conflict and cooperation (average BAR score) and separate measures looking at only conflictive interactions and only cooperative interactions, in order to a) take into account the critique that conflict and cooperation can coexist, b) distinguish between the impact of treaties in reducing conflict versus their impact on promoting cooperation, and c) to avoid missed analysis in cases in which cooperative interactions, in effect, nullify or mitigate the effect of conflictive ones (and vice versa) in a combined measure. Finally, we perform additional robustness tests to consider substantive effects of treaty signature. In the data section below, we describe more fully our dependent and independent variables as well as our controls. Along with the description, we provide hypotheses regarding the expected impact of each variable.

Variables and methods

Treaties

In order to examine whether treaties promote cooperation and/or reduce conflict in the context of water variability we first took the list of all international water agreements listed in the Transboundary Freshwater Dispute Database (TFDD) (TFDD, 2016) covering the period 1948–2008. These riparian country dyads served as our primary unit of observation for statistical analysis.

We then coded all riparian country dyads and identified whether each dyad is governed by at least one treaty. For country dyads with treaties, we noted when the first treaty was negotiated. The time-period after the first treaty is signed was considered the post-treaty period. Since country dyads may sign more than one treaty, we also recorded the number of treaties signed until 2008 (end year of our study) or any other appropriate end year (e.g. if the country ceases to exist prior to 2008). Giordano et al. (2014) suggested that such complex "contributing" agreements are built on the confidence emerging from earlier low-cost agreements. Consequently, we expect those country dyads governed by more treaties to exhibit additional cooperation. In terms of explanatory variables, in separate regressions we used a dummy variable indicating the presence or absence of a treaty between dyad partners (***Treaty***), as well as a continuous variable indicating the number of treaties (***Number of Treaties***) signed between them.

Basin events of conflict and cooperation

We develop our conflict-cooperation indicator based on the water events data stored in the International Water Events Database at Oregon State University (OSU), created under the framework of the Basins at Risk project (BAR) and covering the period 1948–2008 (De Stefano, Edwards, de Silva, & Wolf, 2010; Yoffe et al., 2003).[5] Each event includes a brief summary and source of information coded by date, country pair (dyad), basin, and issue area. Each event is also coded according to its intensity using the BAR scale, which ranges from −7, the most conflictive (war), through 0 (neutral events), and up to +7, the most cooperative (voluntary merging of countries).

To identify whether treaties promote cooperation and/or reduce conflict, we first utilized a combined measure of conflict and cooperation (the dyad's average BAR score). While such a measure is often used to provide a comprehensive assessment of hydropolitical relations in a given basin, riparians often exhibit both types of relations over time (Zeitoun & Mirumachi, 2008). As such, a single combined measure may conflate or distort actual riparian relations. In order to discern more precisely the relation between treaties and riparian relations, we also ran separate regressions with disaggregated measures using only cooperative events and only conflictive events, which is consistent with some of the recent research on transboundary water security (Bernauer & Böhmelt, 2014).

To extract the events examined in this study, we categorized the events data as it relates to country-basin dyads with no treaties and those country-basin dyads with treaties. For those country-basin dyads with treaties, we also compared events before and after a treaty governed the basin in order to compare the two time-periods. As one of the primary goals of this study was to investigate the impact of treaties, in cases with a BAR score of positive 6 (the signing of a treaty), we subtracted one such observation from the total number so as not to attribute the signing of the treaty itself as an outcome of the treaty.

The distribution of events is shown in Figure A1 in the Appendix. As

[3] As articulated above, previous studies investigate the impact of treaty mechanisms and treaty design on conflict and cooperation. Our study focuses on the broader institutional question related to whether treaties can facilitate cooperation specifically under conditions of water variability.

[4] Due to the most recent update of the TFDD treaty database (Giordano et al., 2014) and of the water event dataset (De Stefano et al., 2010), this paper included 220 treaties and 755 water events more than the one by Brochmann (2012).

[5] Other databases utilized in large-n studies pertaining to conflict and cooperation over water include the Correlates of War (used by Tir and Stinnett, 2012), Issues Correlates of War (used by Brochmann & Hensel, 2009) and the International Rivers Cooperation and Conflict dataset (IRCC; used by Kalbhenn and Bernauer, 2012). Despite their merits, the Correlates of War database pertains to all forms of militarized conflicts (so the reason for the conflict may not necessarily be water related) and the Issues Correlates of War only pertains to conflicting claims (contentious events) and research is still underway to collect claims data for basins/countries in Asia, Africa, and parts of Europe. The IRCC database is perhaps the closest to the Basins at Risk database in terms of the types of events collected. Differences between the two databases pertain to the coding of "neutral" events versus years where on-water related events took place, the algorithm used to retrieve news media reports, the event scoring scale, the type of information provided, and the presentation of the data. Ultimately, we elected to use the BAR database given the availability of event data over time (1948–2008). The IRCC database is limited to the years 1997–2007. Additional information about IRCC can be gleaned from Kalbhenn and Bernauer (2012).

can be seen, there are more cooperative events than conflictive ones, and the cooperative events are distributed somewhat more evenly than the conflictive ones, which are heavily skewed towards low-level conflict (-1s).

We used (***AvgBAR***) as a dependent variable, which was the mean of the anti-logged values of conflictive and cooperative relations between the countries. In doing so, we follow previous work using BAR values (e.g., Yoffe & Larson, 2002; Yoffe et al., 2003; Yoffe et al., 2004; Brochmann, 2012). Anti-logs are used instead of actual BAR scores since the intensity of events increases in a non-linear manner, and treating them as a uniform continuous variable would distort their meaning.

Water variability

While water variability is an inherent characteristic across river basins, climate change is predicted to intensify such variability. All else being equal, higher water variability has been argued to lead to political tensions between states sharing river basins (Stahl, 2005; Yoffe et al., 2004).[6] Results presented in Wolf, Stahl and Macomber (2003: 1), for example, demonstrate that "extreme events of conflict were more frequent in marginal climates with highly variable hydrologic conditions, while the riparians of rivers with less extreme natural conditions have been more moderate in their conflict/cooperation relationship."

For the most part, empirical studies investigating international conflict and cooperation over water have utilized static measures of water availability, which often proxy for scarcity. We use the coefficient of variation (CoV) for precipitation to measure climate-driven water variability in each basin dyad. Precipitation data from the Climate Research Unit Time-Series (TS) Version 3.23 (Harris, Jones, Osborn, & Lister, 2014)[7] are the input values for the precipitation CoV. The CoV is calculated to measure inter-annual precipitation over all monthly observations for the relevant time-period (1901–2008).[8] Our rationale for calculating the CoV as a long-term measure is based on our empirical assumption that water variability is embedded in the basin's history and that it is long-term water variability that affects conflict and cooperation over time in a given basin. Our CoV measure likewise follows precedent set by previous studies (De Stefano et al., 2012; Dinar, Dinar, & Kurukulasuriya, 2011, 2010).

The literature touting a relationship between climate change and conflict would suggest that high water variability is not conducive to cooperation. However, some research has found that water scarcity can facilitate treaty formation (Tir & Ackerman, 2009). In fact, some studies have identified a more nuanced relationship between water scarcity (and variability) and treaty formation, whereby formal cooperation is enhanced only up to a certain level of scarcity (and variability), after which formal cooperation is negatively affected as scarcity and variability continue to increase (Dinar, 2009; Dinar, Blankespoor, Dinar, & Kurukulasuriya, 2010, 2011). In light of the findings in the extant literature (e.g., Dinar et al., 2015), our model tests for both linear and nonlinear effects (***Precipitation CoV and Precipitation CoV Squared***) between variability and cooperative/conflictive behavior. We also interact ***Precipitation CoV*** with both our treaty measures. We do not expect treaties to impact conflict or cooperation when variability is minimal.

[6] According to the National Intelligence Assessment (2008) "climate change could threaten domestic stability in some states, potentially contributing to intra- or, less likely, inter-state conflict, particularly over access to increasingly scarce water resources.

[7] Accessed Version TS3.23 on 9 February 2016.

[8] Using run-off data provides another way to measure variability but run-off data is not consistently available on a yearly basis like the precipitation data, which is also available across a much longer time frame. See World Bank Water and Climate Change Project (World Bank, 2009) and CLIRUN-II (Strzepek et al., in preparation).

Geography

Physical attributes of shared rivers have long been recognized as important to understanding conflict and cooperation over transboundary water (e.g. Le Marquand, 1977; Toset et al., 2000). In particular, empirical studies have found that the greater the significance of the particular basin to the respective countries the higher the cooperation evinced. In addition, they have found that the more control a country has over a given river basin the less cooperation (or more conflict) is evinced, presumably because that country perceives more benefits from unilateral action (Espey & Towfique, 2004).

Following Espey and Towfique (2004), we derive two sets of geographic measures. The first set proxies for the level of control a given country within the dyad has over the basin as well as the level of control the entire country dyad has over the basin. The second set proxies for the importance of the basin to a given country within the dyad as well as the importance of the basin to the entire country dyad. The measure for control is estimated by calculating the percentage of the total river basin within the boundaries of each country, while the proxy for importance is derived from the size of the river basin within the country as a percentage of the total area of the country. Two numbers are then obtained for that dyad in order to gauge asymmetry and country-wide nuances: a ratio derived value and a sum-derived value (***Basin Control Sum; Basin Control Ratio; Basin Importance Sum; Basin Importance Ratio***). The variables are calculated from data in OSU's International River Basin Register. The geography variables are time invariant since physical attributes of a basin, generally, do not change drastically overtime. We are able to account for the changes that took place during the collapse of the Soviet Union as well as other major geopolitical changes using the International River Basin Register (International River Basin Register, n.d.).

Governance and democracy

Following the Democratic Peace Theory, scholars have claimed that political regime type should explain conflict and cooperation over the environment. Neumayer (2002), for example, found that democracies tend to exhibit higher environmental commitment. Gleditsch (1998) suggested that democratic countries sharing a river should be more peaceful in their hydropolitical relations in comparison to non-democratic countries. Brochmann and Hensel (2009), who consider conflictual river claims and their subsequent settlement, found that river claims are less likely to begin, and more likely to experience peaceful settlement attempts if claims do begin, between two democracies as opposed to dyads with less democratic forms of government. Tir and Ackerman (2009) found that a country dyad in which both countries are democracies is more likely to negotiate water treaties. Despite this democratic peace rationale, some literature has found insignificant and even negative and significant relationships between measures of democracy and measures of cooperation (Brochmann, 2012).

We test the democracy argument and calculate a combined democracy score for the relevant period of each dyad (***Democracy***) based on the Polity IV database (Marshall, Gurr, & Jaggers, 2013), which ranges from −10 for institutionalized autocracies to 10 for institutionalized democracies. The data for the democracy variable covered the 1945–2008 period.

Overall relations: alliances and militarized conflict

Overall political relations between countries also affect their hydropolitical relations (Brochmann & Hensel, 2009; Yoffe, Wolf, & Giordano, 2003). We used measures of a history of alliances and militarized disputes to proxy for overall relations between states sharing a river basin. Following Tir and Ackerman (2009), we expect states with common security interests to form military alliances, which afford them the opportunity to enhance security, stability and order. In turn, these

shared interests can lead to an increase in mutual trust and result in the attainment of additional objectives in other realms (Keohane, 1984). We, therefore, hypothesize that countries with an overall robust history of alliances will be more likely to cooperate and less likely to experience conflict. The intensity of these events may also be affected. To measure the existence and robustness of alliances, we use the Correlates of War (COW) dataset (Formal Alliances, v4.1). We include a dummy variable (***Alliance***) depicting whether an alliance exists between the riparians over the respective period of the dyad. The data for the alliance variable covered the 1945–2008 period.

Converesely, following Hensel, MitchellSowers, and Thyne (2008) and Brochmann and Hensel (2011), we hypothesize that countries with a history of militarized conflict will be more likely to experience conflictive events and less likely to experience cooperation. To measure the history of militarized disputes, we used the Correlates of War (COW) dataset available up to 2010 (Militarized Interstate Disputes, v4.1). We created a dyadic count of the river riparians involved in militarized disputes. The total number of recorded disputes was used for each river dyad (***Military***).

Power and wealth

The literature provides a variety of views relating to the role of power in international hydropolitics. Some authors have claimed that an asymmetric inter-riparian power relationship impedes international cooperation over shared rivers (Hijri & Gray, 1998; Just & Netanyahu, 1998). Others (particularly those echoing neorealist assumptions) have argued that hegemony, or power asymmetry, facilitates cooperation especially when the stronger party is downstream and initiates and imposes a cooperative regime (Lowi, 1993). Empirical studies have likewise found evidence for the links between power asymmetry, cooperation, and reduced conflict (Song & Whittington, 2004; Tir & Ackerman, 2009; Toset et al., 2000).[9]

Authors associated with the neo-liberal institutionalist school of international relations have seconded the importance of hegemony for explaining international cooperation, but have argued that such asymmetry is not a necessary prerequisite for cooperation (Barrett, 2003; Keohane 1982, 1984; Young, 1989). This argument has also been confirmed in some empirical works on international water treaty formation and negotiation onset (Brochmann & Hensel, 2009; Dinar et al., 2011; Espey & Towfique, 2004).

Further challenging neorealist claims, examples may be cited to demonstrate that even the hegemonic downstream riparian acts in a rather benign nature whereby cooperation is not coerced or enforced, but rather it is encouraged and sustained. As Linerooth writes in the context of pollution control, “the more developed upper riparian nations may wish to create ‘good will’ with their neighbors by contributing more to pollution control while [themselves] benefiting less” (1990; see also Shmueli, 1999).

Given the varied expectations and empirical results regarding power and conflict and cooperation over water, we examined both power asymmetry and asymmetry in wealth (given the wealthier state's ability to create goodwill through incentives). To reflect power and welfare asymmetry, we use annual country-level real GDP and per capita GDP data from Gleditsch (2013). For both measures, a ratio was calculated for each of the dyad countries for each year during the relevant time-period. The average of each of these ratios was then calculated for each dyad, with the larger value country serving as the numerator and the lesser value the denominator, such that larger values always indicate greater asymmetry. The average ratio of GDP (***GDP Ratio***) is a measure of overall power asymmetry, or economic power, while the average ratio of the per capita GDP (***GDP per Capita Ratio***) is a measure of wealth asymmetry, or welfare power.[10]

Regression analysis

We estimated the following regressions:

$$AvgBAR = \beta_0 + \beta_1 Treaty + \beta_2 CoV + \beta_3 CoV^2 + \beta_4 Treaty * CoV + \beta_5 X + \varepsilon \quad (1)$$

$$AvgBAR = \beta_0 + \beta_1 TreatyNumber + \beta_2 CoV + \beta_3 CoV^2 + \beta_4 TreatyNumber * CoV + \beta_5 X + \varepsilon \quad (2)$$

where *AvgBAR* is the mean of the anti-logs of BAR events. (Three different BAR measures were used: a combined measure of conflict and cooperation, conflictive events only, and cooperative events only.) *Treaty* is a binary (0/1) dummy representing the absence or presence of a treaty, *TreatyNumber* is the number of treaties that have been signed by that particular dyad for the given basin (not including the initial treaty signing, as mentioned above), *CoV* and CoV^2 are the coefficient of variation for precipitation in the basin in linear and quadratic form and *X* is a vector of the geographical and political control variables described above.

Results and analysis

The vast majority of dyads examined (nearly 80%) had no events, either cooperative or conflictive included, in the BAR database (Table 1). They therefore, played no role in further analysis of levels of cooperation, and the regression analysis included only those dyads for which there were event data. The mean BAR score for dyads without treaties and those with treaties was similar, with a slightly higher value for those with treaties. Nearly 56% of all observations had military alliances, while over 68% of those with treaties had some sort of military alliance (*Alliance*). Of the observations with at least one militarized dispute, 77% did not have a treaty (*Military*). The mean democracy score (*Democracy*) for observations with treaties was nearly triple the score for observations without treaties. There is almost no difference in the coefficient of variation of precipitation between observations with and without treaties.

Of the 168 treaties that had BAR events, only 40 had events both prior to and post treaty signing. For these, the mean anti-log BAR score for the period before treaty-signing was 25.25, while the mean for the period post treaty signing (not including the treaty signing itself) was 41.36. An ANOVA analysis comparing the means shows that the difference is statistically significant at the 10% level ($p = 0.067$). Though the sample is too small to include relevant effective controls in a regression analysis, this result is consistent with the claim that treaties enhance cooperation and/or reduce conflict. It also serves as a jumping off point for the fuller analysis, as presented below.

Table 2 presents the results from the regressions with the ***Treaty dummy*** variable (Eq. (1)) and Table 3 presents the results with the ***Number of Treaties*** variable (Eq. (2)). We present six sets of regression results for each. These include the combined average BAR score, the conflict only average BAR score, and the cooperation only average BAR score as dependent variables, and model specifications with and without a treaty-CoV interaction term for each.

The mere existence of a treaty seems to have somewhat of a positive impact on cooperation when using the combined BAR measure, but this statistical significance drops out when an interaction variable is

[9] It is important to note that these results and arguments could also be supporting the ‘hydro-hegemony’ school of thought, which argues that the most powerful state in the basin is able to determine the outcome of basin interactions, including cooperation, assuming the most powerful state will benefit from such a policy (Zeitoun and Warner, 2006).

[10] In some cases, GDP data were unavailable prior to 1950. In such cases, the ratios beginning in 1950 were used.

Table 1
Summary statistics.

	All Observations	Observations With Treaties	Observations Without Treaties
Observations	1601	428	1173
Observations with events	320	168	152
Mean BAR value for dyads with events	1.664	1.643	1.686
Average number of treaties per dyad	0.802	3.004	0
Observations with alliances	881	283	598
Observations with militarized disputes	536	121	415
Mean democracy score	0.549	1.446	0.224
Coefficient of variation of precipitation	0.1406	0.1408	0.1399

Table 2
Estimates of the impact of treaty/no treaty on cooperation.

	Avg. Bar Score		Avg. Conflict		Avg. Cooperation	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Treaty (y/n)	6.737*	−5.546	5.439	6.077	6.589	−6.453
	(1.82)	(-0.70)	(1.29)	(1.12)	(1.70)	(-0.64)
CoV	520.5***	430.9***	13.46	19.65	456.8**	344.1**
	(3.86)	(3.46)	(0.29)	(0.28)	(3.20)	(2.48)
CoV^2	−1212.3***	−1097.3***	0.588	−9.525	−884.1**	−709.4**
	(-3.84)	(-3.43)	(0.01)	(-0.07)	(-2.73)	(-2.10)
Treaty* CoV		89.99		−4.661		97.33
		(1.34)		(-0.20)		(1.11)
Ratio Basin (control)	−0.189	−0.162	0.425*	0.425*	−0.132	−0.105
	(-1.10)	(-0.95)	(1.84)	(1.84)	(-0.77)	(-0.62)
Sum Basin (control)	0.0442	0.0309	−0.089**	−0.088**	0.004	−0.009
	(0.78)	(0.53)	(-2.10)	(-2.07)	(0.07)	(-0.14)
Ratio Basin (importance)	−0.006***	−0.005**	−0.054***	−0.054***	−0.005***	−0.004***
	(-2.60)	(-2.55)	(-5.30)	(-5.34)	(-3.83)	(-3.58)
Sum Basin (importance)	−2.831	−3.232	−14.24	−14.24*	−1.594	−2.105
	(-0.39)	(-0.45)	(-1.76)	(-1.75)	(-0.21)	(-0.28)
Alliance	−0.304	−0.510	−3.912	−3.863	4.732	4.363
	(-0.09)	(-0.15)	(-1.22)	(-1.18)	(1.25)	(1.18)
Democracy	−1.392***	−1.399***	−0.346*	−0.347*	−1.258***	−1.264***
	(-3.79)	(-3.77)	(-1.93)	(-1.93)	(-3.32)	(-3.29)
Militarized Disputes (number)	−1.028***	−0.964***	−0.189*	−0.194	−0.620***	−0.584**
	(-3.58)	(-3.49)	(-1.85)	(-1.72)	(-2.79)	(-2.56)
GDP ratio	−0.0183**	−0.019**	−0.006	−0.006	−0.019*	−0.020**
	(-2.22)	(-2.62)	(-0.59)	(-0.59)	(-2.07)	(-2.44)
GDP per cap ratio	−0.155	−0.349	−0.855	−0.828*	−0.280	−0.504
	(-0.21)	(-0.44)	(-1.65)	(-1.73)	(-0.39)	(-0.62)
Constant	−25.87*	−15.06	1.745	1.016	−21.49	−8.705
	(-2.03)	(-1.35)	(0.40)	(0.16)	(-1.57)	(-0.69)
N	312	312	87	87	281	281
R-Squared	0.167	0.172	0.677	0.678	0.161	0.166

Notes: Robust standard errors are in parenthesis, while *** is significance at the 1% level, ** significance at the 5% level, and * significance at the 10% level.

included (Tables 2–1a and 1b), and thus, the results do not provide strong support for the claim that treaties reduce conflict stemming from climatic variability. The mere existence of a treaty also does not seem to impact BAR scores when conflictive and cooperative events are measured separately, though this could be because of the smaller sample size, as not all observations had both cooperative and conflictive events. The results for the number of treaties and their impact on cooperation (Table 3), however, imply a different story. The impact of the number of treaties signed on average BAR score is more statistically significant (Table 3–1a) than for the case of mere presence of a treaty. When conflictive and cooperative events are analyzed separately, the number of treaties is not correlated with reduced conflict, but it is with increased cooperation.[11]

These findings seem consistent with those of Brochmann and Hensel (2011); Brochmann & Hensel, 2009; Brochmann & Gleditsch, 2012, who found that while the existence of a river treaty does not necessarily prevent disagreements (operationalized as conflicting country claims) between states over shared water resources, the presence of at least one treaty over a specific subject may provide an important starting point that increases the likelihood of further negotiations. Thus, the existence of at least one treaty may provide the context for continued negotiations, which could take the form of additional agreements (as suggested by Giordano et al., 2014). The subsequent treaties signed in a given basin may, in turn, suggest at least two possible trends. First, earlier treaties require updating to meet changing needs over time. Second, those subsequent treaties are often more specific in their application in comparison to the original treaty, which tends to be general in scope, and may have a more positive impact on cooperation (Dinar, 2009).

[11] The negative sign on the coefficient for number of treaties in the model specifications including the interaction term (Tables 3–1b and 3b) should not be interpreted as implying that additional treaties actual lower the average BAR score (i.e., are correlated with more conflict). Rather, in dyads with no treaties the effect is 0, and in dyads with treaties the overall effect is the combination of the number of treaties and the number of treaties-CoV interaction term, which is positive.

Table 3
Estimates of the number of treaties on cooperation.

	Avg. Bar Score		Avg. Conflict		Avg. Cooperation	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
No. of Treaties	2.232**	−7.334**	0.454	1.099	2.507**	−8.058**
	(2.00)	(-2.32)	(1.16)	(1.63)	(2.05)	(-2.37)
CoV	511.8***	159.7	7.647	43.62	455.3***	48.93
	(4.01)	(1.33)	(0.16)	(0.62)	(3.30)	(0.38)
CoV^2	−1173.9***	−492.9	7.406	−65.957	−869.5***	−80.17
	(-4.01)	(-1.71)	(0.06)	(-0.44)	(-2.80)	(-0.27)
No. of Treaties* CoV		73.91**		−5.175		82.12**
		(2.44)		(-0.87)		(2.47)
Ratio Basin (control)	−0.266	−0.255	0.366	0.378*	−0.220	−0.214
	(-1.35)	(-1.11)	(1.66)	(1.73)	(-1.05)	(-0.87)
Sum Basin (control)	0.048	0.025	−0.077**	−0.074*	0.008	0.0003
	(0.88)	(0.45)	(-2.04)	(-1.96)	(0.13)	(0.01)
Ratio Basin (importance)	−0.005**	−0.004	−0.054***	−0.054***	−0.004***	−0.002
	(-2.55)	(-1.63)	(-5.18)	(-5.46)	(-3.67)	(-1.38)
Sum Basin (importance)	−3.067	−5.224	−12.07*	−12.28*	−1.992	−4.873
	(-0.44)	(-0.88)	(-1.77)	(-1.79)	(-0.27)	(-0.79)
Alliance	−1.164	−2.552	−2.952	−2.783	3.482	1.146
	(-0.35)	(-0.78)	(-1.10)	(-1.03)	(0.95)	(0.32)
Democracy	−1.332***	−1.254***	−0.317*	−0.344*	−1.201***	−1.167***
	(-3.88)	(-3.94)	(-1.81)	(-1.82)	(-3.38)	(-3.46)
Militarized Disputes (number)	−1.077***	−0.880***	−0.225	−0.249*	−0.676**	−0.503*
	(-3.76)	(-3.21)	(-1.96)	(-1.87)	(-3.06)	(-2.27)
GDP ratio	−0.017**	−0.020***	−0.002	−0.002	−0.018*	−0.022**
	(-2.13)	(-3.12)	(-0.32)	(-0.22)	(-1.98)	(-3.03)
GDP per cap ratio	0.216	−0.393	−0.565	−0.506	0.107	−0.496
	(0.31)	(-0.56)	(-1.19)	(-1.19)	(0.16)	(-0.75)
Constant	−25.99**	10.39	2.576	−0.920	−22.35	19.02
	(-2.09)	(0.96)	(0.50)	(-0.14)	(-1.65)	(1.62)
N	312	312	87	87	281	281
R-Squared	0.192	0.285	0.669	0.672	0.194	0.305

Notes: Robust standard errors are in parenthesis, while *** is significance at the 1% level, ** significance at the 5% level, and * significance at the 10% level.

In terms of addressing climatic variability, in model specifications without an interaction term between CoV and a treaty-related variable, average BAR score increases as a function of climate-driven water variability. The finding is in line with previous scholarship that has found a robust relationship among water variability, scarcity, and cooperation (Tir & Ackerman, 2009). Similar to the results reflected in Dinar et al. (2010, 2015), however, the negative coefficient on the squared CoV term indicates a relationship resembling an inverted U-shaped curve. That is, beyond a certain level of variability, incidences of cooperation seem to decrease. The finding appears limited to cooperation, however, as no statistically significant correlation was found when looking solely at incidents of conflict. This finding is in line with some of the literature more critical of the supposition that climate related variables lead to conflict (e.g., Selby et al., 2018).

A somewhat different picture arises when a treaty-CoV interaction term is introduced. The purpose of such a variable is to evaluate if climate variability affects conflict and cooperation differently in cases in which a treaty exists relative to those not covered by a treaty. In the case of the simple binary treaty variable (exists or does not) (Table 2), introduction of an interaction term was not significant. It did cause the treaty variable in the combined BAR score model to cease being marginally significant, but otherwise did not impact the outcome. When evaluating number of treaties, the introduction of an interaction term was statistically significant for both the combined BAR score and cooperative only events, but not for the conflictive events. This implies that increased climatic variation is associated with increased cooperation in dyads covered by treaties, but not in those not covered by treaties (as the values for both the Number of Treaties variable and the interaction term are 0 in these cases, making the coefficients meaningless for them – see footnote [11]). The values on the CoV and CoV squared variables retain the same sign (positive and negative respectively) but become statistically insignificant.

Geographic variables—proxying for importance and control—elicited significant results, but only for some of the geography measures and models. In particular, we found that when the basin was important for one of the riparians (Ratio Basin – Importance), the result was significant and negative in almost all models. The negative result may be a function of asymmetries in concern for the resource and its utilization (Botteon and Carlo, 1997). For example, certain countries may prioritize more pressing issues over the utilization of the basin (Barkin & Shambaugh, 1999; Darst, 2001; Ovodenko, 2013). These asymmetries may exacerbate environmental or natural resource problems and, in turn, make cooperation more difficult to attain (Ostrom, 1992; Scott, 1974).

The proxy used to measure control was also significant, but only for conflictive events. When considering the control of the basin by one of the riparians, the results indicated that a higher ratio is associated with less conflict. The result may suggest that countries that control a large portion of the basin are less dependent on other basin states and can unilaterally dictate affairs in the basin with little need to interact with other states that control a much smaller portion (Ovodenko, 2016).[12] This finding, however, contrasted with the summative variable proxying for control suggesting increased conflict when both riparians control a large portion of the basin. Gleditsch, Furlong, Hegre, Lacina, and Owen (2006) make a similar discovery, finding that it is the absolute size of the resources (rather than the disparity in the distribution within a dyad) that is a cause for conflict and rivalry.

Of the political controls, democracy and militarized disputes were significant in most models and specifications. Despite the expectations of some studies, democracy seems to have a negative impact on

[12] Compared to symmetric interdependence, Ovodenko argues that asymmetric interdependence lowers the prospects of integrated river management.

cooperation. Brochmann (2012) finds a similar result and suggested that most democracies are located in areas where water is not a critical issue and are able to handle their water issues on their own and develop the resource unilaterally. Focusing on Europe, Bernauer and Kuhn (2010) observed that democracy does not necessarily produce equitable international behavior. Barrett (2003) also challenges the theoretical rational for increased cooperation and participation in environmental agreements among democracies highlighting cases where non-democracies (rather than democracies) were party to an agreement or more inclined to participate.

As for alliances, we expected those dyads with some type of military alliance to also be more prone to cooperation over water. However, our results did not support this expectation. The result is in line with the finding of Long and Leeds (2006) who claim that military alliances that are not linked to a specific issue should not be expected to increase cooperation over that issue. The results for militarized disputes, on the other hand, were highly significant and negative. This reflects the unsurprising finding that countries that are hostile, in general, are also likely to experience conflict over water (Yoffe et al., 2003). Thus, its inclusion as a variable was important as a means of controlling for this correlation and reducing the impact of possible endogeneity.

Results for the power and wealth asymmetries suggest that power asymmetries are negatively correlated with cooperation (though not with conflict). This is in line with some of the international negotiation literature, which suggests that power parity is more conducive to cooperation because it reduces mistrust and the fear of cheating, which is more common in asymmetric situations (Rubin & Brown, 1975). Song and Whittington (2004), who explored the impacts of power asymmetries (measured as relative GDP) on cooperation, also found that in situations of overwhelming power asymmetry cooperation is negatively affected. This finding may also be support the hydro-hegemonic literature, specifically studies that consider counter-hegemonic strategies or contestation by otherwise less powerful states (Zeitoun et al., 2017). An alternative explanation could be that more powerful or hegemonic parties may not feel the need for cooperative measures and can unilaterally dictate terms within the basin (e.g., Fischhendler, Dinar, & Katz, 2011).

Differences in wealth (i.e., GDP per capita) did not seem to make a significant difference. Wealth asymmetry proxies for the ability of richer states to provide financial incentives to poorer states and to induce cooperation. According to Maler (1990), countries that consider offering side-payments may acquire a reputation for being a weaker negotiator and ultimately may decide against providing such financial transfers. Furthermore, the anticipation of side-payments may provide incentives for strategic behavior by the party that can extract large compensation packages (Maler, 1990). Similarly, by providing payment, say, for incentivizing another country to abate pollution, the country providing compensation effectively admits some sort of responsibility for the pollution control even though it was not the main culprit. According to Dombrowsky (2007), side-payments are particularly problematic in international water negotiations as long as the underlying property rights regime is disputed. In addition, according to Bernauer and Kalbhenn (2010) the issue may rest with the fact that side-payments may be better at inducing cooperation among more democratic, richer as well as economically and politically integrated countries.

Conclusions and implications

Our analysis complements recent empirical research which investigates the impact of treaties in reducing conflict and increasing cooperation as well as studies that consider the effectiveness of treaties given their design (Brochmann, 2012; Dinar et al., 2015; Mitchell & Zawahri, 2015; Tir & Stinnett, 2012, 2011, 2009). Our analysis is particularly concerned with how treaties may impact water relations among states under conditions of water variability.

While a large number of dyads have no recorded instances of either cooperation or conflict in the BAR database, among those that do we identify several findings. Firstly, among the relatively small sample of dyads which have recorded event data both pre- and post-treaty, we found a significant increase in the level of cooperation post-treaty, using the combined conflict-cooperation measure. The sample size was too small to conduct more in-depth statistical analysis, with control variables and additional explanatory variables, but is an interesting finding in its own right and is consistent with the findings that treaties enhance cooperation.

In terms of our regression analysis, when using a combined measure of conflict and cooperation, the mere existence of a treaty is only marginally significant and becomes completely insignificant when interacted with variability. The number of treaties variable, on the other hand, is significant when interacted with our measure of variability. A possible explanation for this is that while initial agreements signed between river riparians may be insufficient (or too general) to induce sustained cooperation, they may create the groundwork for additional treaties (more specific and targeted at a given problem in the basin) that do elicit increased cooperation, specifically under conditions of variability.

By disaggregating conflictive and cooperative results, we were also able to evaluate their separate correlations with explanatory variables. Our results do not support the theory that treaties reduce conflict, but, rather, are consistent only with the theory that they promote cooperation. This said, more sophisticated analyses would need to include specific treaty properties to better understand the mechanisms at work. Furthermore, qualitative assessment of the type and nature of cooperation would be useful, given that, as some have mentioned, not all types of cooperation are desirable or indicative of good working relations (e.g., Selby, 2003; Zeitoun & Warner, 2006). A clear conclusion, however, is that reliance on aggregate measures of conflict and cooperation may lead to misunderstanding of actual dynamics occurring in transboundary hydropolitics.

In all, our results are consistent with the claim that treaties seem to be important for promoting cooperation, including under conditions of climatic variability, though not necessarily for reducing conflict. Our study also reveals that multiple treaties governing a particular basin are associated with increased cooperation, particularly under conditions of water variability.

The study's results pertaining to climatic variation are consistent with the theory that high water variability drives states to exhibit cooperative behavior. We found some evidence that once variability increases beyond a certain threshold, cooperative behavior is negatively correlated with cooperation. This is consistent with the claim that climate change could have potentially destabilizing effects on international river basins; however, the finding is not robust in our study, and ceases to be significant in specifications including interaction variables.

Among the various geography variables used, both our proxies for basin importance and, to a lesser extent, control, provided insightful implications for conflict and cooperation over shared international rivers. In particular, when the basin is more important to one country in a basin dyad, more conflict and less cooperation is evidenced. This suggests that asymmetric concern for or dependence on a natural resource or environmental good can generate conflict and inhibit cooperation. More conflict was also evinced when both riparians in the dyad controlled large portions of the basin suggesting lower benefits from cooperation as levels of control increased.

Among our political and economic variables, democracy, military disputes and GDP ratio provided significant results. Democracy is associated with less, not more, cooperation, which seems counter-intuitive to findings in some of the extant literature. However, as Gerlak and Grant (2009) have conjectured, democracies may also have other avenues of regional cooperation through which they are able to deal with their water issues that are not necessarily a function of formalized treaties. Militarized incidents within a dyad negatively affect

cooperation suggesting that a history of political conflict reduces cooperative relations over water (Lowi, 1993). Finally, power asymmetries seem to reduce the level of cooperation. Consequently, strategies to overcome power differentials in basins where cooperation is considered necessary to reduce water-related tensions should be sought. While each basin is described by particular contextual factors that make the general application of asymmetry reducing strategies a challenge, two overall approaches for dealing with asymmetries have been suggested: *leveling the players* and *leveling the playing field* (Zeitoun & Jagerskog, 2009; Zeitoun et al., 2017). While not necessarily dealing with actual power (national material capabilities of the riparians), the former strategy entails increasing the legitimacy or authority of the less powerful side and building its technical capacity. The latter strategy entails harmonizing national policies related to legislation and effective transboundary cooperation, promoting certain international water sharing standards and facilitating the participation of civil society organizations (see also Zeitoun & Jagerskog, 2011). The creation of benefit-sharing initiatives and projects between the parties could also aid in encouraging the parties to realize the advantages of signing a treaty (Phillips et al., 2006).

Acknowledgement

We would like to thank our respective institutions and acknowledge the support from the World Bank Research Support Budget.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.polgeo.2018.08.007.

Appendix

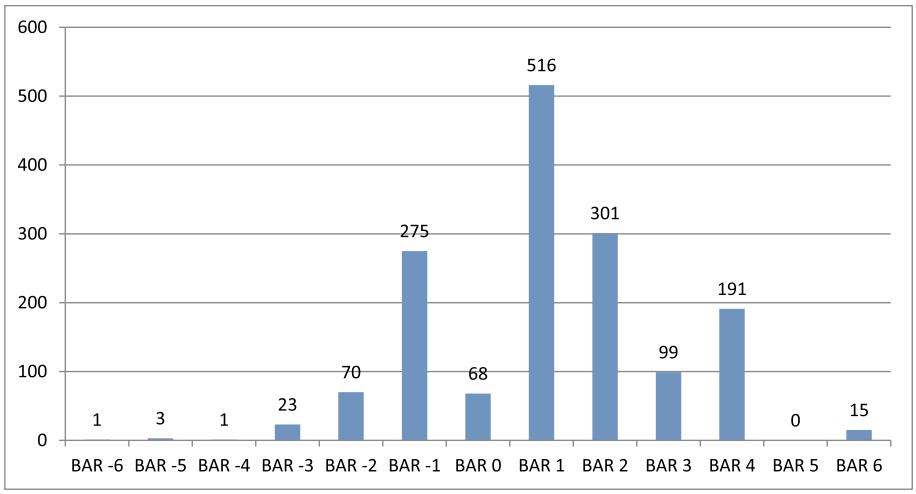

Fig. A1. Distribution of BAR scores for basins sample (initial treaty signing not included).

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